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STUDIES IN ANTIBIOSIS BETWEEN BACTERIA AND FUNGI[1]

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The observations reported herein are the first results of a series of studies in antibiosis between bacteria and fungi, which were begun in the Biological Laboratories of Kent State University in October, 1935. The aim of these investigations is to determine if any of several common species of bacteria are able to inhibit the growth of fungi when grown in close association with them in culture, and to obtain some information regarding the nature of such inhibition.

These studies were undertaken with a number of cultures of bacteria and fungi which were on hand for use in instructional work. The organisms employed are as follows:

Schizomycetes:

Staphylococcus aureus Ros.
Micrococcus ureae Cohn.
Serratia marcescens Bizio.
Klebsiella pneumoniae (Schr.) Trev.
Escherichia coli (Mig.) Cast. et Chalm.
Proteus vulgaris Hauser.
Alcaligenes faecalis Cast. et Chalm.
Bacillus subtilis Cohn.
Bacillus cereus Frank. et Frank.
Bacillus megatherium DeBary.
Actinomyces albus Krainsky.

[1]A resumé of this paper was read before the Ohio Academy of Science at Columbus, Ohio, at the annual meeting of the society in May, 1937.

Eumycetes:
Zygorhynchus mülleri Vuill.
Glomerella cingulata (Stonem.) Sp. et v. Schr.
Anthostomella sp.
Physalospora cydoniae Arn.
Gloesoporium affine Sacc.
Gloeosporium musarum Cke. et Mass.
Colletotrichum lindemuthianum (Sacc. et Magn.) Bri. et Cav.
Botrytis tulipae (Lib.) Hopk.
Cephalothecium roseum Cda.
Volutella fructi St. et H.

In order to determine the effect of the bacteria upon the growth of fungi, each bacterium was grown together with each fungus on dextrose agar, and on corn meal agar, in Petri dishes. The fungous inoculum was placed in the center of the Petri dish. At two centimeters from it, on opposite sides, the agar was inoculated with the bacterium to be tested. Fungi were inoculated at the same time as the bacteria except in experiments in which *Zygorhynchus mülleri* and *Anthostomella* were used. In these two cases, because of the rapid growth of the mycelium, it became necessary to inoculate the bacterium 24 to 36 hours before the fungus, so that the bacterial colonies could become established before the fungous colony was very large. Fungi which sporulated freely, were inoculated by means of a loopful of water suspension of spores. Others were inoculated by means of mycelial transfers. Bacteria were inoculated by using a small loopful of a heavy, water suspension of cells and dividing it between the two points of inoculation in the same Petri dish.

Twelve cc. of Difco agar were used to the Petri dish in all cases. The agar was neutralized with NaOH or HCl. pH determinations were made colorimetrically using a W. A. Taylor comparator. Measurements of fungous colonies were taken with a millimeter rule at intervals of 24 hours, beginning 24 hours after inoculation and continuing until a distinct inhibitory influence was evident, or until the fungous and bacterial colonies were in contact. All tests were carried out in triplicate. Two diameters at right angles to each other were measured on each fungous colony, and the average of the three colonies in each test was recorded. At the first sign of definite inhibition, the

shortest distance between the fungus and the inhibitor was measured. This distance is recorded as "Inhibitory distance."

Of the bacteria employed, *Serratia marcescens*, *Bacillus subtilis*, and *Actinomyces albus* inhibited the growth of fungi. All other bacteria had no appreciable effect upon the growth of any of the fungi against which they were tested. (Plates I and II).

In order to conserve space, only the figures pertaining to the tests with the inhibitor organisms are given in Table I, and contrasted with the controls in each case. The diameters of the fungous colony, are the averages for three cultures. The first figure is the diameter directly between the two bacterial colonies; the second is the diameter at right angles to the first. In the case of the controls, the averages of the minimum and maximum diameters of the three colonies in each test are recorded. The column marked "Inhibitory distance" gives the average minimum distance between the fungous colony and the inhibitor colonies at the time of the first evidence of definite inhibition.

From the figures given in Table I it will be seen that *Actinomyces albus* is the most universal inhibitor of the three under consideration. It inhibits all of the fungi against which it was tested, on both kinds of agar. *Bacillus subtilis* inhibits the growth of 5 of the 10 fungi, on dextrose agar, and that of 8 fungi on corn meal agar. *Serratia marcescens* inhibits the growth of 3 fungi on dextrose agar, and 5 fungi on corn meal agar.

The greatest single amount of inhibition was detected in the case of *Bacillus subtilis* against *Cephalothecium roseum* on corn meal agar. In several tests carried out, the conidia of the fungus used as inoculum, produced germ tubes, but failed to develop further. In one case, a colony was actually developed which, however, failed to reach a diameter exceeding 5 mm.

In all but one case, inhibition, when it occurred, was greater on corn meal agar than on dextrose agar. No correlation exists between rate of growth and degree of inhibition. Rapidly growing fungi may be inhibited as greatly as slowly growing fungi; slowly growing bacteria may inhibit as much as, or more than rapidly growing ones. The inhibitory effect was more pronounced on corn meal agar than on dextrose agar in spite of the fact that all three of the inhibitors grew much more luxuriantly on dextrose agar.

TABLE I

GROWTH OF TEN SPECIES OF FUNGI ON DEXTROSE AGAR AND CORN MEAL AGAR, GROWN IN ASSOCIATION WITH THREE SPECIES OF INHIBITOR BACTERIA, EXPRESSED IN TERMS OF AVERAGE DIAMETERS, IN MILLIMETERS, OF THREE CULTURES

DEXTROSE AGAR

FUNGI	AGE OF FUNGOUS COLONIES IN DAYS						INHIBITORY DISTANCE
	1	2	3	4	5	6	
INHIBITOR ORGANISM—*Serratia marcescens*							
Z. mulleri + bacteria	15x15	39x39	.. ..	.. ..	.. ..	.. ..	..
Control	12x14	40x40					
G. cingulata + bacteria		9x10	14x13	24x25	34x38		
Control		8x 8	17x18	28x29	38x38		
Anthostomella sp. + bacteria	22x23	65x66					
Control	20x21	64x65					
P. cydoniae + bacteria		18x18	28x37	28x44	29x52		2 mm.
Control		19x19	35x35	43x43	55x55		
G. affine + bacteria		12x12	21x21	27x28	33x34		
Control		13x13	21x21	30x30	34x35		
G. musarum + bacteria		21x21	38x38				
Control		20x21	38x38				
C. lindemuthianum + bacteria		17x17	32x44				
Control		17x18	44x45				
B. tulipae + bacteria		11x10	20x21	25x38	29x47		2 mm.
Control		9x 9	21x21	39x39	47x48		
C. roseum + bacteria		10x10	27x36	27x48	27x64		2 mm.
Control		10x10	34x36	51x53	62x65		
V. fructi + bacteria		8x 8	14x14	21x22	27x29	31x35	
Control		6x 6	12x12	20x20	26x26	31x32	
INHIBITOR ORGANISM—*Bacillus subtilis*							
Z. mulleri + bacteria	17x18	41x41					
Control	12x14	40x40					
G. cingulata + bacteria		8x 8	15x16	26x28	35x37		
Control		8x 8	17x18	28x29	38x38		
Anthostomella sp. + bacteria	20x18	69x68					
Control	21x21	64x65					
P. cydoniae + bacteria		18x19	31x35	31x42			2 mm.
Control		19x19	35x35	43x43			
G. affine + bacteria		13x13	21x21	25x30	27x35	28x40	2 mm.
Control		13x13	21x21	30x30	34x35	39x40	
G. musarum + bacteria		20x20	33x36				
Control		20x21	38x38				
C. lindemuthianum + bacteria		18x17	39x44				3 mm.
Control		17x18	44x45				
B. tulipae + bacteria		9x10	20x20	32x36			
Control		9x 9	21x21	38x39			
C. roseum + bacteria		4x 4	10x11	14x19	14x26		17 mm.
Control		10x10	34x36	51x53	62x65		
V. fructi + bacteria		6x 7	12x12	16x19	19x25	20x29	3 mm.
Control		6x 6	12x12	20x20	26x26	31x32	

TABLE I—Continued

DEXTROSE AGAR—Continued

FUNGI	INHIBITOR ORGANISM—*Actinomyces albus*						
	AGE OF FUNGOUS COLONIES IN DAYS						INHIBITORY DISTANCE
	1	2	3	4	5	6	
Z. mulleri + bacteria	17x17	31x39	34x69	.....	.....	.....	2 mm.
Control	12x14	34x35	68x71	.....	.....	.....	.....
G. cingulata + bacteria	.....	9x 9	19x19	22x30	27x40	30x51	5 mm.
Control	.....	8x 8	17x18	28x29	38x38	47x48	.....
Anthostomella sp. + bacteria	20x20	25x65	27x90	.....	.....	.....	5 mm.
Control	20x21	64x65	90x90	.....	.....	.....	.....
P. cydoniae + bacteria	.....	17x19	24x34	26x40	26x50	.....	5 mm.
Control	.....	19x19	35x35	43x43	55x55	.....	.....
G. affine + bacteria	.....	13x13	19x20	24x29	26x34	28x39	6 mm.
Control	.....	13x13	21x21	30x30	34x35	39x40	.....
G. musarum + bacteria	.....	21x22	30x40	30x54	30x78	.....	3 mm.
Control	.....	20x21	38x38	51x52	76x77	.....	.....
C. lindemuthianum + bacteria	.....	18x17	26x44	28x57	28x62	.....	5 mm.
Control	.....	17x18	44x45	55x57	62x64	.....	.....
B. tulipae + bacteria	.....	11x11	20x20	24x37	28x46	28x64	7 mm.
Control	.....	9x 9	21x21	38x39	47x48	61x63	.....
C. roseum + bacteria	.....	10x10	31x40	31x50	31x60	.....	1 mm.
Control	.....	10x10	34x36	51x53	62x65	.....	.....
V. fructi + bacteria	.....	7x 6	13x13	18x20	20x26	21x31	7 mm.
Control	.....	6x 6	12x12	20x20	26x26	31x32	.....

CORN MEAL AGAR

	INHIBITOR ORGANISM—*Serratia marcescens*						
Z. mulleri + bacteria	19x18	40x42	.....	.....	.....	.....	.....
Control	13x13	36x36	.....	.....	.....	.....	.....
G. cingulata + bacteria	.....	8x 9	16x15	26x25	34x34	.....	.....
Control	.....	7x 8	15x16	27x28	33x34	.....	.....
Anthostomella sp. + bacteria	15x16	29x50	33x81	.....	.....	.....	3 mm.
Control	13x15	51x52	84x85	.....	.....	.....	.....
P. cydoniae + bacteria	.....	21x21	35x35	.....	.....	.....	.....
Control	.....	21x21	36x37	.....	.....	.....	.....
G. affine + bacteria	.....	11x12	18x20	25x30	30x38	34x45	7 mm.
Control	.....	10x10	18x18	26x27	36x36	42x42	.....
G. musarum + bacteria	.....	19x19	32x35	37x46	.....	.....	3 mm.
Control	.....	18x19	33x33	44x44	.....	.....	.....
C. lindemuthianum + bacteria	.....	16x16	35x39	.....	.....	.....	.....
Control	.....	15x16	38x40	.....	.....	.....	.....
B. tulipae + bacteria	.....	14x15	23x24	37x38	45x47	.....	.....
Control	.....	15x15	24x24	38x38	46x46	.....	.....
C. roseum + bacteria	.....	8x 9	20x27	22x36	24x47	.....	8 mm.
Control	.....	8x 9	26x29	34x37	46x50	.....	.....
V. fructi + bacteria	.....	7x 7	12x12	17x18	23x25	26x31	3 mm.
Control	.....	7x 8	12x13	18x19	23x24	30x30	.....

TABLE I—Continued

CORN MEAL AGAR—Continued

FUNGI	AGE OF FUNGOUS COLONIES IN DAYS						INHIBITORY DISTANCE
	1	2	3	4	5	6	
	INHIBITOR ORGANISM—*Bacillus subtilis*						
Z. mulleri + bacteria	17x17	36x38	.....	.....	.....	.....	.....
Control	13x13	36x36	.....	.....	.....	.....	.....
G. cingulata + bacteria	.....	9x 9	14x15	25x26	34x35	.....	.....
Control	.....	7x 8	15x16	27x28	33x34	.....	.....
Anthostomella sp. + bacteria	15x16	33x51	34x83	.....	.....	.....	3 mm.
Control	13x15	51x52	84x85	.....	.....	.....	.....
P. cydoniae + bacteria	.....	21x21	30x35	37x42	.....	.....	3 mm.
Control	.....	21x21	36x37	41x42	.....	.....	.....
G. affine + bacteria	.....	11x11	19x19	25x29	26x37	27x43	4 mm.
Control	.....	10x10	18x18	26x27	36x36	42x42	.....
G. musarum + bacteria	.....	19x19	29x34	37x45	.....	.....	3 mm.
Control	.....	18x19	33x33	44x44	.....	.....	.....
C. lindemuthianum + bacteria	.....	16x16	25x31	35x39	.....	.....	5 mm.
Control	.....	15x16	38x40	49x51	.....	.....	.....
B. tulipae + bacteria	.....	16x16	25x25	33x39	42x49	.....	3 mm.
Control	.....	15x15	24x24	38x38	46x46	.....	.....
C. roseum + bacteria	.....	0x 0	0x 0	0x 0	0x 0	.....	20 mm.
Control	.....	9x 8	26x29	34x37	46x50	.....	.....
V. fructi + bacteria	.....	8x 8	11x11	14x18	17x24	19x29	11 mm.
Control	.....	7x 8	12x13	18x19	23x24	30x30	.....
	INHIBITOR ORGANISM—*Actinomyces albus*						
Z. mulleri + bacteria	21x21	25x33	29x64	.....	.....	.....	7 mm.
Control	13x13	36x36	66x66	.....	.....	.....	.....
G. cingulata + bacteria	.....	8x 9	15x18	16x27	18x35	20x42	10 mm.
Control	.....	7x 8	15x16	27x28	33x34	45x46	.....
Anthostomella sp. + bacteria	14x16	16x37	17x63	.....	.....	.....	11 mm.
Control	13x15	51x52	84x85	.....	.....	.....	.....
P. cydoniae + bacteria	.....	18x20	23x23	23x39	23x49	.....	10 mm.
Control	.....	21x21	36x37	41x42	49x50	.....	.....
G. affine + bacteria	.....	10x10	13x17	15x25	19x30	21x34	12 mm.
Control	.....	10x10	18x18	26x27	36x36	42x42	.....
G. musarum + bacteria	.....	15x17	15x26	17x33	19x43	.....	10 mm.
Control	.....	18x19	33x33	44x44	63x64	.....	.....
C. lindemuthianum + bacteria	.....	13x16	15x34	16x42	16x47	.....	12 mm.
Control	.....	15x16	38x40	49x51	57x58	.....	.....
B. tulipae + bacteria	.....	13x13	16x22	16x26	17x30	17x34	10 mm.
Control	.....	15x15	24x24	38x38	46x46	56x57	.....
C. roseum + bacteria	.....	7x 8	18x23	21x31	23x41	.....	10 mm.
Control	.....	8x 9	26x29	40x42	46x50	.....	.....
V. fructi + bacteria	.....	7x 7	9x12	9x15	9x16	10x16	13 mm.
Control	.....	7x 8	12x13	18x19	23x24	30x30	.....

When these facts were established, experiments were begun to obtain some information regarding the cause of inhibition. Three factors which seemed important to investigate as probable causes of inhibition were: First, a change in the pH of the medium induced by the inhibiting organism; second, a food depletion of the medium by the inhibiting organism; third, a secretion of some soluble substance which was toxic to the fungi. All three of these factors have been reported in the literature (1, 2, 3, 4, 6, 7, etc.) as causes of one type of inhibition or another in microorganisms.

The experiments undertaken were limited to the effect of *Actinomyces albus* on the growth of *Colletotrichum lindemuthianum*, on dextrose agar and nutrient agar prepared as follows: Fifteen flasks, each containing 100 cc. of neutral Difco dextrose broth, were inoculated with *Actinomyces albus*, one every two days. The organism was allowed to grow until thirty days had elapsed from the time of the inoculation of the first flask. Thus, a series of flasks was obtained which contained *Actinomyces* colonies ranging in age from 2 to 30 days. Another series of flasks containing Difco nutrient broth was treated in the same manner. At the end of the thirty-day period, the organism was removed from the broth by filtration through filter paper. The water lost by evaporation was added, and the liquid in each flask was divided into two 50 cc. portions. To one of these portions, the same proportion of dehydrated medium was added as was originally used in the preparation of the medium, to replace that which had been used by the *Actinomyces*. Additional food was withheld from the second 50 cc. portion; 1½% agar was added, and the media were distributed into test tubes and sterilized in the autoclave at fifteen pounds for fifteen minutes. The agars to which more food was added shall be referred to henceforth as "Fortified-dextrose-inhibitor agar" and "Fortified-nutrient-inhibitor agar." The agars from which additional food was withheld shall be referred to as "Dextrose-inhibitor agar" and "Nutrient-inhibitor agar."

pH determinations showed that the pH varied from 6.5 to 8.8 in the dextrose agars containing inhibitor filtrate, and from 6.4 to 8.8 in the corresponding nutrient agars. A series of dextrose agar and nutrient agar tubes of various pH values corresponding to those of the agars prepared from the *Actinomyces* filtrates, was then prepared. These served as

TABLE II

EIGHT DAYS GROWTH OF *Colletotrichum lindemuthianum* IN FORTIFIED-DEXTROSE INHIBITOR AGAR (COLUMN A), DEXTROSE-INHIBITOR AGAR (COLUMN B), AND DEXTROSE AGAR (CONTROL), EXPRESSED IN AVERAGE MAXIMUM DIAMETERS, IN MILLIMETERS, OF THREE CULTURES

Age of *Actinomyces*-Culture Filtrate from which Inhibitor Agars were Prepared	A		Control		B		Control	
	pH	Diameter in mm.	pH	Diameter in mm.	pH	Diameter in mm.	pH	Diameter in mm.
2 days	7.2	83	7.2	81	6.5	66	6.5	84
4 "	7.2	84	7.2	81	6.9	66	6.9	83
6 "	7.2	62	7.2	81	7.1	58	7.1	82
8 "	7.7	37	7.7	79	7.6	25	7.6	80
10 "	7.7	29	7.7	79	7.6	17	7.6	80
12 "	8.2	22	8.2	78	7.8	21	7.8	80
14 "	8.0	23	8.0	79	8.0	26	8.0	79
18 "	8.4	22	8.4	80	8.3	28	8.3	80
20 "	8.5	18	8.5	77	8.4	18	8.4	80
22 "	8.6	19	8.6	78	8.5	18	8.5	77
24 "	8.8	21	8.8	76	8.8	24	8.8	76
26 "	8.8	18	8.8	76	8.8	19	8.8	76
28 "	8.8	18	8.8	76	8.8	19	8.8	76
30 "	8.8	18	8.8	76	8.8	18	8.8	76

TABLE III

EIGHT DAYS GROWTH OF *Colletotrichum lindemuthianum* IN FORTIFIED-NUTRIENT INHIBITOR AGAR (COLUMN A), NUTRIENT-INHIBITOR AGAR (COLUMN B), AND NUTRIENT AGAR (CONTROL), EXPRESSED IN AVERAGE MAXIMUM DIAMETERS, IN MILLIMETERS, OF THREE CULTURES

Age of *Actinomyces*-Culture Filtrate from which Inhibitor Agars were Prepared	A		Control		B		Control	
	pH	Diameter in mm.	pH	Diameter in mm.	pH	Diameter in mm.	pH	Diameter in mm.
2 days	6.5	50	6.5	49	6.4	55	6.4	53
4 "	6.7	53	6.7	55	7.0	54	7.0	49
6 "	7.5	29	7.5	47	7.6	29	7.6	48
8 "	7.9	26	7.9	45	8.0	31	8.0	43
10 "	7.8	29	7.8	47	8.1	28	8.1	43
12 "	8.3	18	8.3	44	8.6	21	8.6	43
14 "	8.2	19	8.2	44	8.6	24	8.6	43
18 "	8.5	0	8.5	44	8.7	15	8.7	40
20 "	8.4	15	8.4	43	8.8	15	8.8	39
22 "	8.4	15	8.4	43	8.8	16	8.8	39
24 "	8.4	16	8.4	43	8.8	16	8.8	39
26 "	8.4	19	8.4	43	8.8	12	8.8	39
28 "	8.4	0	8.4	43	8.8	22	8.8	39
30 "	8.4	15	8.4	43	8.8	13	8.8	39

controls in testing the possibility that a change in pH was responsible for inhibition. After sterilization, the different agars were poured into Petri dishes and three plates of each kind of agar were inoculated with a loopful of a heavy, water suspension of *Colletotrichum lindemuthianum*. The colonies resulting were measured every 24 hours for eight successive days. The results are summarized in Tables II and III.

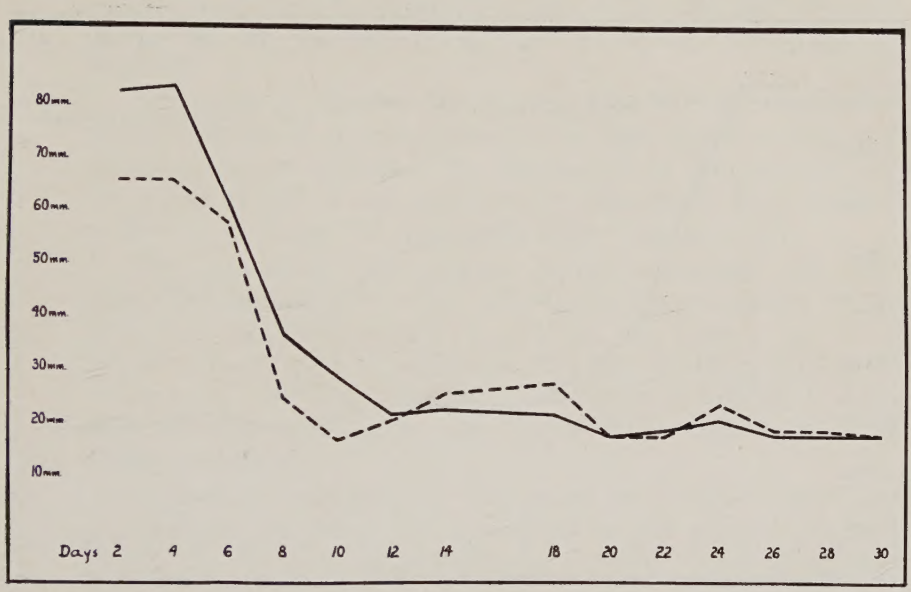

Fig. 1. Eight days growth of *C. lindemuthianum* on Dextrose-inhibitor agar and Fortified-dextrose-inhibitor agar, both prepared from filtrates in which *Actinomyces* had grown for different periods of time.
————Fortified-dextrose-inhibitor agar.
----------Dextrose-inhibitor agar.

The results of these experiments establish the fact that the presence of the living *Actinomyces* itself is not necessary for the inhibition of fungous growth since sterilized filtrates of *Actinomyces* cultures produce similar inhibitory effects. As the brief discussion which follows will point out, neither food depletion of the medium (Fig. 1), nor a change in pH brought about by the *Actinomyces* (Fig. 2), is responsible for the inhibition of growth of *Colletotrichum lindemuthianum*. It seems quite probable, therefore, that the antibiotic phenomena herein described are due to the presence of some substance which is toxic to the fungus.

An analysis of the figures in Tables II and III reveals that food depletion of the medium by the *Actinomyces* was not a factor in the inhibition of growth of *C. lindemuthianum*. A comparison of columns A and B in Table II shows that the fungus grew better on fortified-dextrose-inhibitor agar prepared from filtrates of *Actinomyces* cultures 2 to 10 days old than on dextrose-inhibitor agar prepared from filtrates of *Actinomyces*

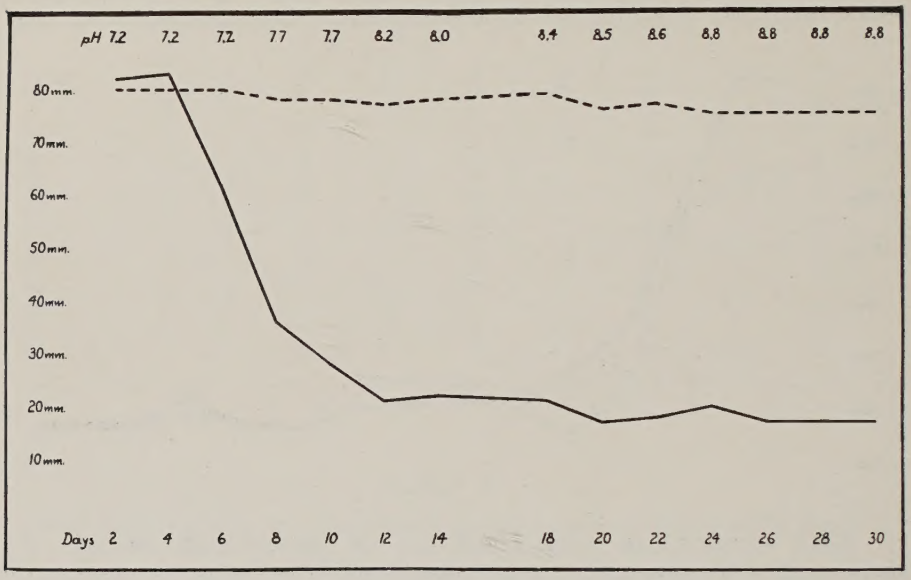

Fig. 2. Eight days growth of *C. lindemuthianum* on Fortified-dextrose-inhibitor agar prepared from filtrates in which *Actinomyces* had grown for different periods of time, compared with controls of comparable pH values.
————Fortified-dextrose-inhibitor agar.
----------Control, Dextrose agar.

cultures of similar ages. Since each 50 cc. portion of fortified filtrate received the same amount of additional dehydrated medium, and since food material already present was inversely proportional to the age of the colonies grown, the amount of food material in the fortified-dextrose-inhibitor agar varied up to almost double the original amount. In the inhibitor agars containing a small amount of inhibitory substance, an increase in growth due to greatly increased food supply is evident. However, with an increase in amount of inhibitory substance, variation in food supply does not seem to influence growth. This is indicated by the similar size of the colonies on fortified-

dextrose-inhibitor agar and dextrose-inhibitor agar made from the 12 to 30 day old culture filtrates.

From a comparison of the figures in Tables II and III it is evident that, in the presence of a large amount of food and a relatively small amount of inhibitory substance, the increase in growth of the fungus is entirely due to the dextrose contained in the food, the effects of which overbalance the inhibitory effects of the toxic substance. Dextrose agar and nutrient agar differ in composition only in that the former contains dextrose.

Although it cannot be denied that *C. lindemuthianum* apparently grows slightly better in an acid medium than in an alkaline one, as indicated by the growth of the controls, still the effect of pH is too slight to be considered as a factor in antibiosis between the organisms under consideration.

The antibiotic phenomena herein recorded, are quite probably due either to the secretion of a substance by the inhibitor organism, which is toxic to the fungus, or to the production of such a substance through an alteration of the medium by chemical reaction. This toxin is soluble in water, diffusible through agar, and to a large degree, at least, thermostable.

Organisms belonging to the genus *Actinomyces* have been reported in the literature as inhibiting the growth of fungi. Porter (5) mentions *Actinomyces* as a strong inhibitor of fungal growth. Millard and Taylor (4) report antagonism between two Actinomycetes in the soil, and Tims (3) has studied an Actinomyces which secretes a toxic substance which inhibits the growth of Pythium. During the past few years, the senior writer has observed that colonies of organisms belonging to this genus, occurring as contaminations in Petri dishes in the routine laboratory work with fungi, frequently inhibited the growth of many different fungi. Experiments, the results of which will be published soon, indicate that a large number of species of *Actinomyces* exhibit this property.

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LITERATURE CITED

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Fig. A. Complete inhibition of *Cephalothecium roseum* by *Bacillus subtilis* on corn meal agar.

Fig. B. Inhibition of *Cephalothecium roseum* by *Bacillus subtilis* on dextrose agar.

Figs. C, D. *Serratia marcescens* inhibiting growth of *Cephalothecium roseum* on corn meal agar (C) and dextrose agar (D).

Figs. E, F. *Alcaligenes faecalis* growing together with *Cephalothecium roseum* on corn meal agar (E) and dextrose agar (F). No inhibitory effect.

Figs. G, H. *Serratia marcescens* growing together with *Colletotrichum lindemuthianum* on corn meal agar (G) and dextrose agar (H). No inhibitory effect.

Figs. I, J. *Colletotrichum lindemuthianum*. Controls on corn meal agar (I) and dextrose agar (J).

Figs. K, L. *Actinomyces albus* inhibiting growth of *Colletotrichum lindemuthianum* on corn meal agar (K) and dextrose agar (L).

LIZARDS IN INSECT CONTROL

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Lizards consume large numbers of injurious insects each year, thus constituting an important biological factor in environmental resistance. The extent of the benefit derived from lizards depends upon a number of factors, including (1) the abundance and distribution of lizards in a given area, and (2) the abundance and availability of the insect pests as compared with the availability of other acceptable food.

The feeding habits of any particular lizard species may be such as to make it especially useful or useless in the control of a particular insect pest. For instance, the larger lizards usually fed more extensively upon caterpillars, grasshoppers and larger insects, often disregarding tiny insects such as beet leafhoppers. On the other hand, several of the smaller lizard species, and to a less extent immature specimens of some of the larger lizards, fed more readily upon small insect pests if such occurred in abundance.

A number of agricultural insect pests breed in areas frequented by lizards and are extensively fed upon by these animals. This often results in a perceptable limitation of pest multiplication, with resulting benefits to agriculture.

Satisfactory estimates of lizard population density are difficult to make. Several seasons of study of small tracts of land in Tooele County, Utah, led the writer to conclude that populations of from fifty to four hundred northern brown shouldered utas per acre were not unusual in favorable breeding and feeding locations. Where small areas of unusual insect abundance occur in desert areas, such as on narrow strips of succulent roadside Russian thistle bordered on both sides by large dry areas of shadscale, high lizard populations have been observed especially during the evening feeding period shortly before sunset. This condition was particularly evident in the case of *Uta stansburiana stansburiana*. The data which follow relate to lizards collected in Utah.

Coleonyx variegatus (Baird). Two specimens of the banded gecko were collected at St. George, April 26, 1935, by C. F. Smith. Recognizable stomach contents consisted of 1 leafhopper; 2 beetles, 3 Lepidoptera, caterpillars; and 1 spider.

Crotaphytus collaris baileyi (Stejneger). The western collared lizard was usually collected upon the top of boulders on range land. Most of the specimen's stomachs were well distended with insect food. Grasshoppers, caterpillars and ants are three of the groups of insects most destructive to range plants; the first two had been fed upon commonly by the specimens examined. An examination of 93 stomachs showed 50 Lepidoptera to be present, 47 being caterpillars in 47 stomachs; 85 Coleoptera in 29 stomachs; 168 Orthoptera in 49 stomachs, 106 being nymphs, and nearly all of the specimens being grasshoppers; 11 Hemiptera in 7 lizards; 22 Diptera in 9 stomachs; 19 Homoptera in 7 stomachs, 18 being cicadas; 168 Hymenoptera in 39 lizards, only 19 being ants in 3 specimens; 1 Odonata; 3 Neuroptera; and 9 spiders in as many stomachs. In addition, one stomach contained 95 parasitic roundworms.

Crotaphytus wislizenii (Baird and Girard). The leopard lizard is another range species, which has an apparent "preference" for larger insects, particularly grasshoppers. Stomachs of 92 specimens were examined, showing 213 Orthoptera present in 87 stomachs, 62 being nymphs in 28 stomachs, all but a few of the specimens being grasshoppers; 14 Lepidoptera in 8 stomachs, all caterpillars; 4 Hemiptera; 3 Homoptera, cicadas; 8 Coleoptera in 6 stomachs; 13 Diptera in 11 stomachs, 10 of which were robber flies; 20 Hymenoptera in 14 stomachs, only 4 of which were ants; 5 spiders in as many lizards; and 2 round worms in one stomach. Federal entomologists estimated that $2,000,000 worth of poison bait would be needed to control the grasshoppers during 1937 in the western United States, and the Federal Government appropriated funds to make effective control possible. Lizards eating from one to several grasshoppers each day do much to retard grasshopper abundance wherever such lizards and grasshoppers occur together in abundance.

Callisaurus draconoides ventralis (Hallowell). The stomachs of 35 desert gridiron-tailed lizards were examined, the total contents consisting of 11 Orthoptera, grasshoppers, 6 being nymphs; 18 Neuroptera, 14 being ant lion larvae, and 4 aphis lions; 23 Isoptera in 1 stomach; 33 Hemiptera in 11 stomachs, 13 false chinch bugs and 13 Pentatomidae being the principal injurious forms; 12 Homoptera, 16 being leafhoppers, of which 4 in four stomachs were beet leafhoppers, and 4 aphids; 21 Coleoptera, including 1 Buprestidae, 4 Chrysomelidae, and 2 Scarabaeidae; 55 Lepidoptera in 15 stomachs, all but two being caterpillars; 88 Hymenoptera in 23 stomachs, only 10 of which were ants in 3 stomachs; 29 Diptera in 7 stomachs; 49 Arachnida in 16 stomachs; besides 6 plant blossoms and one plant leaf. This lizard evidently selects a wider variety of food than some of the less active species.

Uta levis Stejneger. The Rocky Mountain tree uta differs to some extent in food habits from its more common relative, *Uta s. stansburiana*. An examination of the stomachs of 44 *Uta levis* showed them to contain 3 Orthoptera, grasshoppers; 16 Hemiptera; 16 Homoptera, 6 being leafhoppers, of which two were beet leafhoppers in two stomachs; 30 Diptera, 11 being Calliphoridae; 28 Coleoptera, 1 being a larva;

21 Lepidoptera, of which 18 were caterpillars; 2 Thysanura; 70 Hymenoptera, 36 being ants in 11 stomachs; besides 11 Arachnida.

Uta stansburiana stansburiana (Baird and Girard). The northern brown shouldered uta feeds to a considerable extent upon small insects, although nymphal and adult grasshoppers occur rather commonly in its diet. An examination of 3,541 stomachs of this species showed the following food material to be in recognizable condition: 1 Thysanura; 635 Collembola; 1,093 Orthoptera, 749 being nymphs, of which 6 were Mantidae, 3 Gryllidae, most of the others being grasshoppers; 305 Isoptera or termites; 27 adult and 60 nymphal Neuroptera; 1 Ephemeridae; 23 Odonata; 85 Thysanoptera; 3,349 Hemiptera, including 51 adult *Lygus elisus* and *L. hesperus*, 7 lygaeid nymphs, 53 Pentatomidae, 682 adult and 55 nymphal *Nysius ericae* or false chinch bugs; 4,470 adult and 14,221 nymphal Homoptera, of which 2,713 were adult and 7,971 nymphal beet leafhoppers, *Eutettix tenellus* (Baker), besides 381 adult and 90 nymphal leafhoppers of other species, 14 Fulgoridae, 3 Cercopidae, 11 Membracidae, 1,323 aphids, 6 psyllids, and 22 Coccidae; 346 adult and 101 larval Coleoptera, including 6 Staphlynidae, 5 Cucujidae, 60 Chrysomelidae, 1 Scolytidae, 3 Curculionidae, 7 Tenebrionidae, 9 Melyridae, 2 Buprestidae, 65 Scarabaeidae, 10 adult and 2 larval Elateridae, 17 Silphidae, 1 Meloidae, and 2 Dermestidae; 708 Lepidoptera, all but 12 being caterpillars, including a large number of diamond back moth larvae; 304 adult and 454 larval Diptera, including 128 *Chloropisca glabra*, 10 Calliphoridae, 40 mosquitoes, 11 Muscidae, 15 Asilidae, 18 Chironomidae, 5 Tipulidae, 3 Tabanidae, 1 Simuliidae; 2,670 Hymenoptera, including 2,522 ants, 61 Chalcididae, 17 Sphecidae, 18 Apidae, 13 Ichneumonidae, 6 Braconidae, 10 Chrysididae, 10 Andrenidae, 1 Dryinidae, and 7 Vespidae; a number of Arachnida and several plant fragments also were present in the stomachs. An examination was made of 4,021 brown shouldered utas collected among Russian thistle, *Atriplex rosea*, and other hosts of the beet leafhopper, during the seasons of 1930 to 1935, inclusive. It was found that 2,249, or approximately 55.96 percent of the stomachs contained *Eutettix tenellus*, the total number of beet leafhoppers being 10,576 nymphs and 5,390 adults, or 15,966 in all. With lizard populations in desert breeding areas of the beet leafhopper estimated at from 50 to 400 per acre in various Tooele County, Utah, areas and the average being 7.09 beet leafhoppers for each stomach containing *E. tenellus*, this lizard seems to be an important aid to the agriculturists of the west.

Sceloporus graciosus graciosus (Baird and Girard). An examination of 1,332 sagebrush swifts, collected among sagebrush, rabbit brush, Russian thistle, and miscellaneous other plants, showed the following to be present: 2 Collembola; 203 adult and 289 nymphal Orthoptera, of which 4 were Gryllidae, nearly all of the others being grasshoppers; 89 Isoptera; 17 adult and 11 larval Neuroptera, 7 being Chrysopidae; 1 Odonata; 5 Thysanoptera; 672 adult and 809 nymphal Homoptera, of which 120 were adult and 122 nymphal beet leafhoppers, besides 119 other leafhoppers, 7 Cercopidae, 1 Membracidae, 601 aphids, 5 Fulgoridae, 1 Chermidae, and 1 Coccidae; 642 adult and 809 nymphal

Hemiptera, including 257 adults and 382 nymphs of the false chinch bug, 18 adult and 26 nymphal *Lygus elisus* and *L. hesperis* combined, 68 Pentatomidae, 12 Tingidae, as well as 45 adult and 5 nymphal *Geocoris decoratus*, an insect predator of the beet leafhopper; 169 adult, 602 larval, and 2 pupal Lepidoptera; 314 adult and 20 maggots of Diptera, including 6 Asilidae, 34 *Chloropisca glabra*, 6 Chironomidae, 5 Muscidae, 2 Calliphoridae, 2 mosquitoes, 1 horse fly, as well as 6 Sarcophagidae, 4 Tachinidae, and 1 Pipunculidae; 540 adult and 79 larval Coleoptera, including 136 Chrysomelidae, 17 Staphlynidae, 1 Melodiae, 6 Elateridae, 18 Scarabaeidae, 17 weevils, 1 Histeridae, 2 Cucujidae, 7 Tenebrionidae, 2 Dermestidae, 3 Buprestidae, as well as 109 ladybird beetles and 53 Carabidae; 3,357 Hymenoptera, 2,756 being ants, 10 Chalcididae, and such beneficial forms as 14 Ichneumonidae and 15 honey bees. In addition was recognized 189 spiders and mites; 1 scorpion; 1 small lizard, a *Sceloporus g. graciosus*, 83 round worms, 9 insect eggs; 2 mollusc shells; and a few plant fragments, the latter apparently accidentals.

Sceloporus magister Hal. Desert scaly lizards contained numerous insects in the 44 stomachs examined, recognizable material being: 7 Orthoptera in 5 stomachs; 1 Isoptera; 2 Neuroptera; 10 Hemiptera in 5 stomachs, 4 being false chinch bugs; 13 Homoptera in 3 stomachs; 88 Coleoptera in 23 stomachs; 83 larval Lepidoptera in 16 stomachs; 4 Diptera; 733 Hymenoptera in 33 stomachs of which 698 were ants in 28 stomachs. In addition 7 spiders; and 19 parasitic roundworms were found in 4 stomachs.

Cnemidophorus tessellatus tessellatus (Say). Desert whiptail lizards are common in a number of sections of Utah. The stomachs of 326 specimens were examined; these contained: 117 Neuroptera in 50 stomachs, 67 being Myrmelionidae in 30 stomachs, and 5 aphis lions; 1,643 termites in 39 stomachs; 262 Orthoptera in 113 stomachs, including 52 adult and 188 nymphal grasshoppers, 4 Mantidae, 16 crickets in 13 stomachs, and 1 phasmid; 75 Hermiptera in 30 stomachs, including 7 false chinch bugs, 13 pentatomids, 2 mirids and 2 tingids; 388 Homoptera in 57 stomachs, including 36 adult and 23 nymphal beet leafhoppers in 15 stomachs, 31 leafhoppers of other species, 11 Fulgoridae, 11 cicadas, 27 coccidae in 3 stomachs, 9 aphids in 3 stomachs, 70 adult and 62 nymphal psyllids in 5 stomachs; 223 Coleoptera in 112 stomachs, including 21 Tenebrionidae in 16 stomachs, 22 Scarabaeidae in 20 stomachs, 3 weevils, 32 Chrysomelidae in 5 stomachs, and 16 long horned beetles in 3; 111 Diptera in 50 stomachs, 2 being larvae, and 37 pupae; 775 Lepidoptera in 186 stomachs, 731 being caterpillars in 169 lizards and 27 pupae, 23 *Plutella maculipennis* larvae being found in the stomach of one specimen collected among *Cheirinia repanda*; 43 Hymenoptera in 28 stomachs, 33 being ants. Also contained were 93 spiders, 2 mites, and 1 small *Uta s. stansburiana*.

BASIDIOMYCETES OF THE CHAGRIN RIVER DISTRICT OF NORTHERN OHIO

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The following notes are a preliminary contribution to the knowledge of the fungi in the Chagrin River district of Northern Ohio. Only the Basidiomycetes are dealt with in this paper. Two-thirds of these were found on "Vallevue Farm," the former estate of Judge Andrew Squire, located in the northeastern section of Cuyahoga County. The rest were collected upon the farm of Harvey Bingham, Glen Rock, Bainbridge Township, Geauga County.

"Vallevue Farm" includes over two hundred and fifty acres of rolling fields, pastures and woodland. It has recently come into the possession of Western Reserve University, whose Biological Department expects to make an intensive study of the flora and fauna found there. The woodland is primarily beech and sugar maple. The most northern woods has been untouched for ten or twelve years, and most of the trees are over fifty years of age. Through part of the woodland a small stream has cut a deep ravine through the shale. Here beech, maple, dead chestnut, hemlock, birch and tulip are found.

Soil acidity varies from 3.7 pH under the hemlocks to an average of 4 pH in the woodland and ravine, and 5 pH in the open. Rainfall in this area is usually greatest in April, when there is over two inches, with an average of one inch in both January and September.

The collecting ground in Bainbridge Township is similar to that of the Squire property. Beech and maple predominate, with birch, ironwood and black cherry common. The land is rolling, with ravines and small streams.

The fungi have been photographed either in their natural environment or soon after collection. Sixty lantern slides and photographs of the Squire Estate fungi are on file in the Biological Department of Western Reserve University. Specimens of the Agaricaceae from the Squire Estate are there, also. The Polyporaceae, Thelaphoraceae, Hydnaceae, and Gasteromycetes are in the writer's collection. The Geauga County fungi are in the Oberlin College Herbarium.

H. C. Beardslee has determined the rarer Agariacaceae, and L. O. Overholts and F. O. Grover many of the Polyporaceae. Unusual spore measurements and other striking characteristics have been noted. The frequency of occurrence is indicated by the letters C for common, I for infrequent, and S for a single collection.

I. Cuyahoga County, Squire Estate Collections.
Fifty-six species are represented.

Amanita phalloides Fries.
Beardslee says, "Volva with free margin, spores globose, 7–9 μ." S.
Clitocybe clavipes Fries. S.
Clitopilus abortivus Berk. and Curt.
Normal specimens, found with abortive forms, had spores salmon in mass, nucleate, elongated angular, 6.4–7 x 4–4.8 μ. I.
Collybia radicata Fr. S.
Collybia semitalis Fr.
Beardslee says, "This is a very interesting specimen. . . . In the dried specimens the spores are 5–6 μ. long, smaller than my measurements of fresh spores (7–9 μ). Your plant agrees in having the gills turn yellow when cut, and apparently they have blackened somewhat." I.
Coprinus micaceus Fr.
Spores 4.8–6.4 x 8–9 μ., purple black. Found in good condition as late as December first. I.
Flammula spumosa Fr.
Spores 8–10 x 5–6 μ., smooth, brown. S.
Hypholoma sublateritium Fr.
Spores 6–7 x 3.5–4 μ. C.
Lentius vulpinus (Sow.) Fr.
Spores 2.5–3.5 μ, ovoid, hyaline, white in mass. On sugar maple. S.
Lepiota procera Fr. S.
Leptonia serrulata Fr.
Beardslee says, "Spores angular, 7–9 x 4–5 μ." S.
Marasmius fagineus Morgan. I.
Panus stipticus Fr. C.
Pholiota adiposa Fr.
Spores obovoid, 8–10 x 5–7 μ, ochre, smooth. I.
Pleurotus sapidus Kalch.
Spores 7–10 x 4–4.5 μ, oblong, smooth. I.
Schizophyllum commune Fr. C.
Hydnochaete olivaceum (Schw.) Banker. I.
Hydnum ochraceum (Pers.) Fr.—*Steccherinum ochraceum* (Pers.) S. F. Gray. I.
Hydnum macrodon Pers. ex Fries.—*Oxydontia macrodon* (Fr.) Miller. I.
Peniophora cinerea (Fr.) Cke. C.
Solenia anomala (Pers.) Fr. S.
Stereum cinerascens (Schw.) Massee. C.
Stereum rameale Schw. C.

Stereum hirsutum (Willd.) Fr. C.
Stereum lobatum (Kuntze) Fr. C.
Stereum frustulosum (Pers.) Fr. C.
Thelephora pallida (Pers.) Fr. I.
Exidia glandulosa Fr. I.
Daedalea unicolor (Bull.) Fr.—*Cerrena unicolor* (Bull.) Murr.
Spores ovoid, 4–6 x 3–4 μ, hyaline, smooth; on beech. C.
Daedalea confragosa (Bolt.) Fr.
Spores 4–6 x 2 μ, on maple. I.
Fomes applanatus (Pers.) Wallr.—*Elfvingia megaloma* (Lév.) Murr.
Spores 7–8 x 6 μ, ovoid, smooth, brownish, on sugar maple. C.
Lenzites flaccida (Bull.) Fr. var. *variegata* (Fr.) Cost. and Dufour (Rea. Brit. Basid. 613. 1922).—*L. variegata* Fr. (Bourdot and Galzin, Nym. d. Fr. 580. 1927).—*L. betulina forma variegata* (Fr.) Lloyd.
This seems to be the common form in the United States. The pilei are thin and have broad bands of orange between wood colored zones. Spores elliptical, some curved, hyaline, smooth, 4–6.5 x 2–4 μ.
Polyporus adustus (Willd.) Fr.—*Bjerkandera adusta* (Willd.) Karst. I.
Polyporus biformis (Klotzsch.) Berk.—*Coriolus biformis* (Klotzsch.) Pat.
Spores 4–7 x 2 μ, curved, hyaline, hyphae 4 μ, on beech. C.
Polyporus brumalis (Pers.) Fries.—*Polyporus polyporus* (Retz.) Murr. S.
Polyporus caesius (Schrad.) Fr.—*Tyromyces caesius* (Schrad.) Murr.
Spores 4–5 x 1–2 μ, curved, smooth. I.
Fomes connatus (Weinm.) Gill—*Fomes populinus* (Schum.) Cooke.
Spores 3–5 μ, globose, hyaline, on maple. S.
Polyporus delectans Peck.—*Spongipellis delectans* (Pk.) Murr. S.
Polyporus galactinus Berk.—*Spongipellis galactinus* (Berk.) Pat. S.
Polyporus gilvus (Schw.) Fries—*Hapalopilus gilvus* (Schw.) Murr. C.
Polyporus hirsutus (Wulf.) Fries—*Coriolus nigromarginatus* (Schw.) Murr. C.
Polyporus pargamenus Fr.—*Coriolus prolificans* (Fr.) Murr.
Spores 6–8 x 2–4 μ, smooth, hyaline, curved, on beech. C.
Spores 6–8 x 2–3 μ, smooth, curved, on black cherry. C.
Polyporus rigidus Lév. (resupinate form).
Spores 3–4 x 2–3 μ, hyaline. S.
Polyporus sulphureus (Bull.) Fr.—*Laetiporus speciosus* (Batt.) Murr.
Spores 6–8 x 5–6 μ, hyaline, on chestnut. S.
Polyporus tephroleucus Fr.—*Polyporus albellus* Am. Auth., not Peck.
Spores 4–5 x 1–1.5 μ, smooth. Hyphae of context 4 μ diam., unbranched. Clamps present. I.
Polyporus tulipiferus (Schw.) Overholts.—*Irpiciporus lacteus* (Fr.) Murr.
Spores 5–7 x 2 μ, curved, hyaline, smooth, on beech. C.
Polyporus versicolor (L.) Fr.—*Coriolus versicolor* (L.) Quel. C.
Poria eupora Karst. S.
Trametes Sepium Berk.—*Coriollelus Sepium* (Berk.) Murr. I.
Phlebia radiata Fr. C.
Geaster Triplex Jung. S.
Lycoperdon gemmatum Batsch.
Spores spiny, spherical, 4–5.5 μ.; capillitium thread brown, 6μ, little if any branching, ends obtuse. C.

Lycoperdon pyriforme Schaeff.
Spores brown, spherical, 3.7–4 μ, with large oil drop; capillitium threads 3.6–4.5 μ, ends blunt, branched occasionally, pale olivaceous. C.
Lycoperdon umbrium Pers.
Spores spherical, 3.5–4 μ, smooth, with oil drop; capillitium threads 4–5 μ, ends blunt. I.
Scleroderma aurantium (Vaill.) Pers.—*Scleroderma vulgae* (Hornem.) Fr.
Spores spiny, 10–12 μ, dark brown, spherical; hyphae light brown, 6–8 μ, with tapering ends. C.

II. Geauga County, Bainbridge Township, Bingham Farm Collections.—Thirty-two species are reported.

Exidia glandulosa Fr. C.
Guepinia spathularia (Schw.) Fr., on *Prunus serotina*. S.
(See G. W. Martin, Am. Jour. Bot. 23: 627–629, 1936, for validity of this name.)
Schizophyllum commune Fr. Common on *Carpinus* and *Malus*.
Coniophora arida (Fr.) Karst.
Spores 8.8–11 x 6.8 μ. On *Carpinus*.
Peniophora cinerea (Pers.) Cooke. On *Carpinus* and *Quercus alba*. C.
Stereum sericeum Schw. On *Carpinus*. C.
Corticium investiens (Schw.) Bres. C.
Odontia crustosa (Pers.) Quel. On *Carpinus*.
Merulius ceracellus Berk. and Curt. On *Malus*. S.
Phlebia radiata Fr. On *Malus* and *Prunus serotina*. I.
Daedalea confragosa (Bolt.) Fr. On Black Cherry. C.
Lenzites trabea (Pers.) Fr. (Overholts, Bull. Penn. State Coll. 316:5, 1935).
Lenzites vialis Peck.—*Gloephyllum trabeum* (Pers.) Murr. Lamelloid form. On *Prunus serotina*.
Polyporus biformis (Klotzsch.) Berk.—*Coriolus biformis* (Klotzsch.) Pat. C.
Polyporus brumalis (Pers.) Fr.—*Polyporus polyporus* (Retz.) Murr. On *Prunus serotina*. S.
Polyporus albellus Peck.—*Polyporus chioneus* Am. Auth. not Fries. On *Prunus serotina*.
Polyporus caesius (Schrad.) Fr.—*Tryomyces caesius* (Schrad.) Murr. On *Tilia* and *Ulmus americana*. I.
Polyporus fumosus (Pers.) Fr.—*Bjerkandera fumosa* (Pers.) P. Karst.
Spores smooth, hyaline, ellipsoid-ovoid, 2–3 x 4.5–6 μ. I. On *Ulmus ameri*.
Polyporus hirsutulus Schw.—*Coriolus hirsutulus* (Schw.) Murr. On *Acer and Fraxinus*.
Polyporus hirsutus Fr.—*Coriolus nigromarginatus* (Schw.) Murr. On *Amelanchier canadensis*.
Polyporus psrgamenus Fr.—*Coriolus prolificans* (Fr.) Murr. On *Prunus serotina*.
Polyporus picipes Fr. On *Ulmus americana*. S.
Polyporus pubescens (Schum.) Fr.—*Coriolus pubescens* (Schum.) Murr. On *Prunus seratina*. S.

Polyporus tulipiferus (Schw.) Overholts—*Irpiciporus lacteus* (Fr.) Murr. On *Quercus alba* and *Prunus seratina.*

Polyporus versicolor (L.) Fr.—*Coriolus versicolor* (L.) Quel. On *Prunus seratina and Platanus occidentalis.* C.

Poria candidissima (Schw.) Cooke. Det. L. O. Overholts.

This *Poria* seems to be a rare species. In his study of *Porias* in 1923, Overholts was able to examine only six specimens from this country. Two characteristics are unique: the spores are echinulate, and the hyphae have occasional swollen walls next to the cross walls. Spores 2.5–4 μ. On beech.

Poria corticola Fr. Det. L. O. Overholts.

Poria eupora (P. Karst.) Cooke. On *Acer.*

Poria ferruginosa (Schrad.) Bres. On *Carpinus.*

Poria medulla-panis (Pers.) Cooke. On *Castanea.*

Poria versipora (Pers.) Fr. On *Carpinus.*

Polyporus conchifer (Schw.) Fr.—*Poronidulus conchifer* (Schw.) Murr. On *Ulmus americana.*

Fomes fulvus (Scop.) Gill—*Pyropolyporus fulvus* (Scop.) Murr. On *Prunus.*

Spores 3–5 x 4–6 μ.

THE RATE OF GROWTH OF FINGER NAILS IN RELATION TO THEIR CYSTINE CONTENT IN ARTHRITICS

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INTRODUCTION

Several investigators, notably Berthold (1), Dufour (2), Sharpey-Schäfer (3), Heller (4) and Voit (5), employing different methods of measurement, have reported that finger nails grow on the average of 1 mm. in ten days, that is, one-tenth of a millimeter (0.100 mm.) per diem. Results obtained by the writer on the growth of finger nails of a large number of apparently normal, healthy individuals agree in general with this rate. As to the factors upon which nail growth depends numerous ones have been suggested. Thus Berthold found that nails grow more rapidly in summer than in winter, in children than in adults, on the right than on the left hand and that the rate of different finger nails differs according to the length of the finger, the most rapid being on the middle then in order the ring, index and little finger and slowest on the thumb.

Moreover, it is well known among clinicians that nails exhibit a hypersensitiveness to disease, especially the acute infectious type as, for example, smallpox, rheumatic, typhoid and scarlet fever. The writer is now engaged in a study of the effect of various diseases and other nutritional disturbances, such as pregnancy, hyperthyroidism and hypothyroidism, on the rate of growth of the nails. Concomitant with this study has arisen the question concerning the relation of the growth of finger nails to their cystine content.

Much interest in recent years has been attached to the physiologico-chemical significance, dietary importance and therapeutic value of cystine. The chemistry of cystine need not be dwelt upon here other than to remark that it is a sulfur compound which forms the basic constituent of keratin, a substance composing such epidermal derivatives as hair, nails, hoofs, horns, feathers, et cetera. As to the physiological significance of cystine, various workers, notably Hopkins and Dixon (6), Lewis (7), Lewis and Root (8), have pointed out that sulfur compounds play an important part in the metabolic processes of cells, especially oxidation and reduction. Accord-

ing to Sullivan and Hess (9) intoxication factors such as bacteria and toxins tend to deplete these regulators of metabolism and thus divert them from their normal reservoirs such as nails. They analyzed the finger nail clippings of 26 normal individuals and 103 arthritics and found that the average cystine content of the nails of the normals was 11.69%, whereas the average for the arthritics was 9.77%. They conclude, therefore, that this decreased cystine content of the nails of arthritics is an index of a toxic factor.

In the light of these and other researches it is now believed by many workers that, notwithstanding the possibility of numerous etiological agents or predisposing causes, the prime factor in arthritis and allied rheumatoid conditions is diminished oxidation resulting from impaired sulfur metabolism—hence the rationale for parenteral sulfur therapy, many favorable results of which have been reported in recent years.

In addition to the reports bearing on the chemotherapeutic action of cystine significant studies have been reported in the last few years concerning the relation between dietary cystine and the growth, texture and cystine content of animal hair and wool. Although the results reported are not unanimous, most of the evidence presented indicates that the growth and histological structure of these epidermal derivatives depend largely on the presence or absence of cystine in the diet.

As a result of these various researches concerning the importance of cystine it seemed logical in connection with the writer's study of the effect of disease on the growth of nails to determine whether or not there is any marked relationship between the growth of the nails and their cystine content. The object of this paper, therefore, is to report the results of a study based on thirty-five arthritic patients who were under observation and treatment at the Arthritic Clinic of the State Street Dispensary, College of Medicine, Ohio State University.

METHODS

The method employed for determining the daily rate of growth of the finger nails was as follows: A mark was made on each nail at the central convex line of the lunula, when present, by means of a sharp, curved scalpel. The daily rate of growth was ascertained by dividing the distance which the mark traversed from the anterior margin of the lunula by the number

of days elapsing from the date of marking to the date of measuring. Thus let us suppose the distance of the mark from the lunula in 30 days was 3.2 mm. The daily rate of growth would be (3.2 mm. divided by 30 days) 0.106 mm. The nails on which a lunula could not be observed were marked at a determined distance, usually five millimeters, proximal to the anterior central border of the nail bed which is visible through the nail. The distance which the nail grew in these cases was calculated by subtracting the distance between the mark and the anterior border of the nail bed from the distance between the latter point and the mark used as a measuring point. Hence if the mark was placed at a point 5 mm. from the anterior border of the nail bed and 30 days later it was 2.8 mm. from the latter the amount of growth would be (5 mm. minus 2.8 mm.) 3.2 mm. The daily rate of growth, calculated the same as above, would be (3.2 mm. divided by 30 days) 0.106 mm.

All measurements were made by means of a Vernier caliper calibrated in millimeters. In order to insure a fine degree of accuracy the two measuring arms of the Vernier were sharpened and the marks on the nails, as well as the adjustments of the measuring arms of the Vernier to these marks, were made under magnification with the use of a binocular loupé.

The cystine content of the finger nails was determined by Miss Edith M. Miller, Department of Pathology, Ohio State University, who utilized Sullivan's method with a few modifications. The writer wishes to acknowledge his indebtedness to Miss Miller for furnishing the data on the cystine content of the finger nail clippings and to Dr. Geo. E. Watson, director of the Arthritic Clinic, for permission to use the clinical patients for this study.

In Table I are tabulated the results of the present study on the rate of growth of finger nails of arthritic patients in relation to their cystine content.

The rates of growth tabulated here represent the mean daily rate of growth of all the finger nails of each subject and is expressed in thousandths of a millimeter. Thus, for example, in subject G. A. the mean rate of growth of all his finger nails is .110 mms. daily. The cystine content of the nails of each subject is shown in the last column of the table and is expressed in percentage. At the bottom of the table are given the mean age of the group, the mean daily rate of growth and the mean cystine content of the nails of all the subjects.

Although it is not the object of this paper to make a comparative study of the daily rate of growth or cystine content of the finger nails of arthritic patients with normal individuals, it

TABLE I

DAILY RATE OF GROWTH OF FINGER NAILS CORRELATED WITH CYSTINE CONTENT

(35 subjects)

SUBJECT	AGE	SEX	MEAN GROWTH	CYSTINE %
G. A.	50	M	110	12.0
C. B.	25	M	118	11.6
G. C.	59	M	091	12.2
W. C.	52	M	071	10.5
L. C.	30	M	123	8.7
I. E.	69	F	097	14.5
A. E.	51	F	106	14.2
W. F.	62	M	128	12.5
J. F.	53	M	080	6.8
E. F.	65	M	068	12.5
L. G.	56	F	114	12.5
F. G.	45	M	095	11.5
A. G.	34	F	106	17.6
R. H.	65	F	111	9.2
W. H.	50	M	104	9.7
M. K.	74	M	085	10.1
C. K.	48	M	091	9.7
H. K.	20	F	094	11.5
M. L.	58	F	112	10.2
G. M.	22	M	107	14.1
R. M.	49	M	059	13.0
A. M.	63	F	091	8.3
E. M.	35	F	131	14.6
F. M.	54	M	085	12.3
B. M.	44	M	107	10.6
O. N.	31	M	103	11.3
A. N.	35	F	101	12.0
S. O.	45	M	093	10.2
M. S.	51	F	089	11.1
F. S.	67	F	122	9.1
H. S.	51	F	081	11.4
M. S.	68	F	107	10.8
W. T.	27	M	102	16.5
E. T.	39	M	072	12.6
M. V.	39	M	122	11.3
Mean	48.1		099	11.6

can be observed from the results recorded in the table that in the case of the 35 arthritic patients studied the mean daily rate of growth is 0.099 mm. which is essentially similar to normal, being only 0.001 mm. below one-tenth of a millimeter, the accepted normal rate. According to Sullivan and Hess (9)

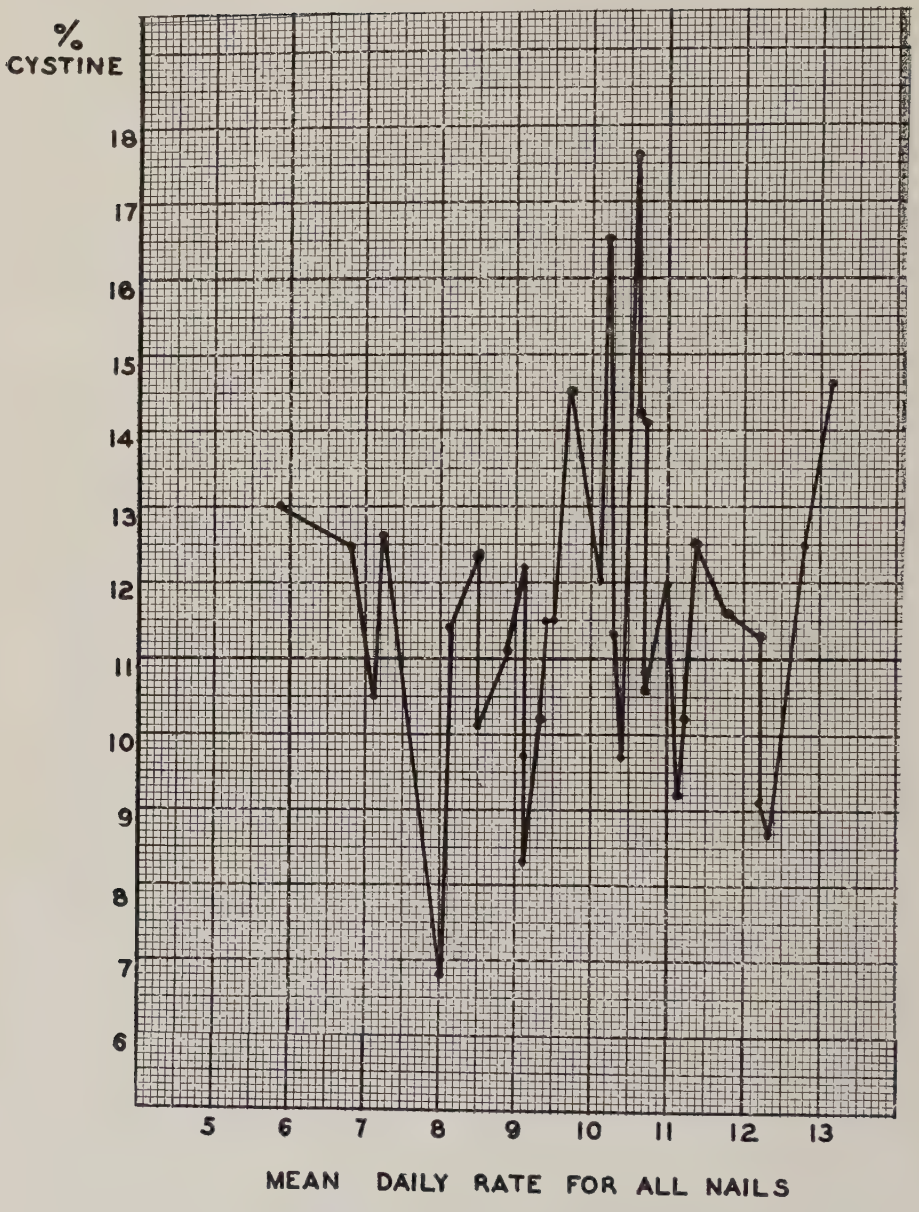

Fig. 1. The mean daily rate of growth of the finger nails in relation to their cystine content.

the average normal cystine content of finger nails is roughly 12% as compared with arthritics in which it is in general lower. As is shown in the table the mean percentage of cystine contained in the finger nails of the 35 patients examined is 11.6% which is only four-tenths percent (0.4%) below the accepted normal.

In regard to the question as to whether or not there is any correlation between the rate of growth of finger nails and their cystine content in arthritics it is logical to conclude from the results shown in Table I and graphically represented in Figure 1 that no such correlation exists. Take for example the cases in which the cystine content of the finger nails ranges from 12% to 12.5%, the rates of finger nail growth vary much more considerably, thus 068 (E. F.), 085 (F. M.), 091 (G. C.), 101 (A. N.), 110 (G. A.), 114 (L. G.), and 128 (W. F.) thousandths of a millimeter. Similarly if we compare the five lowest rates of nail growth, namely, 059 (R. M.), 068 (E. F.), 071 (W. C.), 072 (E. T.) and 081 (H. S.), with their respective cystine content the range of variation of the latter is likewise quite considerable, thus 13, 12.5, 10.5, 12.6 and 11.4 percenta. Neither is the highest mean daily rate of nail growth (131 thousandths of a millimeter) correlated with the highest cystine content (17.6%) or the lowest rate (.059 mm.) with the lowest cystine content (6.8%) or vice versa. Moreover, it is evident that should a correlation exist between these two factors we should expect to have either a gradual ascending or a descending curve, depending of course upon whether a high cystine content corresponds to a high rate of growth, which we should expect, or to a low rate.

SUMMARY AND CONCLUSIONS

1. The problem as to whether the daily rate of growth of finger nails of arthritics is correlated with their cystine content was undertaken in view of other researches concerning (1) the importance of sulfur compounds, such as cystine, to the metabolic processes of cells; (2) the significance and relation of cystine of the nails to toxicity and disease, such as arthritis; (3) the beneficial effects of dietary cystine on the growth of animal hair and wool.

2. The amount of growth of the finger nails of 35 arthritic patients used in this study was determined by measuring the distance which a mark, previously made, grew from the convex

central line of the lunula of the nail or toward the anterior border of the nail bed in a given length of time by means of a Vernier caliper calibrated in millimeters.

3. The daily rate of finger nail growth was calculated by dividing the amount of growth by the number of days of growth. Only the mean daily rate of all the nails of each patient was recorded. Considerable variation in daily rates of finger nail growth existed between patients. The mean finger nail rate of the 35 patients was 0.099 mm. daily, which may be taken as normal, since this figure does not differ significantly from the accepted normal rate, that is 0.100 mm.

4. The cystine content of the nail clippings of these patients likewise varied considerably, the mean percentage being 11.6, which is slightly below the normal (12%).

5. There is no evidence in the present study of any correlation between the daily rate of finger nail growth and the cystine content of the nails in arthritics.

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THE MORPHOLOGY OF THE ALIMENTARY TRACT OF THE BLISTER BEETLE, EPICAUTA PENNSYLVANICA, DEG.

(COLEOPTERA: MELOIDAE)

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INTRODUCTION

In central Ohio the black blister beetle, *Epicauta pennsylvanica*, Deg., is found in abundance in September feeding on the pollen of goldenrod (Solidago). This member of the Meloidae is wholly black, ranging in length from 7 to 13 mm.

METHODS

Specimens collected were placed in Kahle's fixative immediately after being killed with potassium cyanide. Twenty-four hours later they were transferred to seventy per cent alcohol. Borax-carmine was used as an *in toto* stain before embedding in paraffin. Serial sections were stained in haemalum (one part to two parts alcohol) for seventeen minutes, and in Fast Green for thirty seconds. Difficulty was experienced in getting good sections of large structures. This was thought to be due to the hardening effect of the higher alcohols. A Dioxan technique was tried, hoping to toughen the material and make it more elastic. This method, however, removed the *in toto* stain and was abandoned.

ACKNOWLEDGMENTS

The author is grateful for the criticisms and advice of Dr. C. H. Kennedy, who supervised the work, and whose "Methods for the Study of the Internal Anatomy of Insects" was used as a manual of technique. Many valuable suggestions were also given by Dr. P. E. Schaefer.

THE GROSS ANATOMY

The morphology of the alimentary tract (Plate I, Fig. 1) of *E. pennsylvanica* Deg., is relatively simple. It has three main divisions: The fore-intestine (stomadaeum), the mid-intestine (mesenteron), and the hind-intestine (proctodaeum). Of these the stomodaeum and the proctodaeum are of ectodermal origin since they are formed by anterior and posterior invaginations respectively of the external germ layer. The mesenteron originates from the endoderm.

The fore-intestine is straight and simply constructed. It extends through the thorax and first abdominal segment. The mid-intestine is much larger in diameter and occupies the greater part of the abdominal cavity. It extends from the anterior of the first to the middle of the seventh abdominal segment. The hind-intestine is about one-half the diameter of, and approximately one and one-third times the length of the mid-gut.

The Fore-Intestine

There is no distinct pharynx, oesophagus, and proventriculus in the fore-intestine. The oesophagus is narrow anteriorly, gradually increasing in diameter until it empties into the mid-gut. The comparative size of the anterior, middle and posterior regions of the oesophagus may be noted in Plate II, Figures 1, 2 and 3. The gradual enlargement of the oesophagus is the only semblance of a proventriculus or gizzard. A lack of a definite chamber of mastication is typical of pollen feeding insects. The fore-intestine extends into the mid-intestine forming a pronounced oesophageal valve (Plate III, Fig. 5). There is no external indication of this valve.

The Mid-Intestine

The mid-intestine is larger in diameter than any other part of the alimentary tract, tapering at either end where it joins the fore-intestine and hind-intestine respectively. Externally the mid-gut appears folded or wrinkled transversely. This wrinkled appearance is due to the infolding of the thickened epithelial tissue.

The Hind-Intestine

There are three definitely differentiated regions forming the hind-intestine. These regions are the ileum, the colon, and the rectum. Just posterior to the mesenteron the ileum bends forward dorsally, extending anteriorly about one-half the length of the mid-intestine. The colon begins at the posterior bend of the ileum in its position over the mesenteron. The colon enlarges toward the rectum, where it constricts abruptly. This constriction is more pronounced dorsally. The rectum is about two-thirds the diameter of the colon at their point of union. Anterior to the anal opening the rectum enlarges slightly.

Malpighian Tubules

Six Malpighian tubules enter the alimentary tract at the point where the mid-intestine and hind-intestine meet. These tubules make many convolutions throughout the body cavity of the beetle, eventually entering under the connective tissue which covers the colon. The exact point at which the tubules enter under this tissue was not determined definitely, but it is in the bend of the hind-intestine where the ileum and colon meet. The tubules are found in numerous short bendings along the entire length of the colon, ending abruptly at the rectal constriction.

THE HISTOLOGY OF THE ALIMENTARY TRACT

The Fore-Intestine

Just as there is no morphological differentiation of the fore-intestine, so also there is no histological separation into a pharynx, oesophagus, and proventriculus. The wall of the fore-intestine is made up of the following five regions listed successively from interior to exterior: (1) a chitinous inner lining, or intima; (2) a thin epithelium; (3) longitudinal muscles; (4) circular muscles; and (5) a membrane of connective tissue covering the whole fore-intestine.

The intima is apparently composed of two layers. This is evident from the fact that a definite inner part of it stains much deeper with Fast Green than does the outer part. Within this intima there are six or seven deep longitudinal infoldings which extend the entire length of the fore-intestine. The folds increase in size toward the mesenteron, and as many as three or four smaller infoldings may occur between the larger ones at the region where the fore-intestine and mid-gut meet (Plate II, Fig. 4). The intima is modified on the interior surface and assumes a serrate appearance. In some specimens these serrations were further modified forming definite spines.

The epithelium of the fore-intestine is a single layer of elongated and flattened cells. This tissue follows the outer surface and the infoldings of the intima.

Although the longitudinal muscles occur around the entire circumference of the stomodaeal wall, they are massed for the most part at the base of, and in the infoldings of the intima and epithelium.

The next outer histological region of the fore-intestine is composed of circular muscles, which vary in the number of layers from one to three.

As the oesophagus enlarges posteriorly the wall becomes thinner. The longitudinal muscles are fewer, and the circular muscles limited in number.

There is no external indication of an oesophageal valve. It can, however, be readily demonstrated by pulling the oesophagus forward from the mesenteron. This action will pull from within the mesenteron an extension of the oesophagus. This extension of the oesophagus into, and for a distance of one-third the length of the mesenteron, is the oesophageal valve (Plate III, Fig. 5). Just at the point of entry of the oesophagus into the mid-gut, gross dissection reveals six splinter-like fingers of chitin. These chitinous structures are light brown in color, and run along the longitudinal axis of the alimentary tract almost to the end of the extension of the oesophagus into the mesenteron. A microscopical examination of a cross section shows these chitinous fingers to be located on the interior surface of the intima (Plate III, Fig. 6). These pieces of chitin remain unstained in mounted serial sections, and are not united at any point but are attached to, or embedded in, the layer of intima. R. T. Everly, in his study of the Margined Blister Beetle, found only four such structures. He also found that they were attached anteriorly only and were free and separate posteriorly.

The inner surface of the intima of the oesophageal valve of the Margined Blister Beetle, according to Everly, is definitely more modified than the anterior oesophagus. He found the same true of the pyloric valve region. No such definite differentiation is to be found between the anterior intima of the oesophagus of *E. pennsylvanica* and the intima of the oesophageal valve, or between the intima of the pyloric valve and that of the remainder of the hind-intestine.

In the region where the oesophagus and mesenteron unite fatty tissue is part of the wall of the alimentary tract. Circular muscles surround the valve under and posterior to this fatty tissue. There is a definite ring of these muscles which probably act in constricting and closing the alimentary passage. The epithelium of the oesophagus is continuous, extending into the valve well towards the end of the extension. This epithelium also is continuous anteriorly from this point around the outside of the ring of circular muscles, eventually uniting with the anterior epithelium of the mesenteron. Before it unites with the mesenteric epithelium, the epithelium of the oesophageal valve evaginates into the crypt of the first fold of the mid-gut epithelium. This forms a collar-like structure of intima and epithelium around the oesophageal extension.

The Mid-Intestine

The mid-gut is composed of epithelium, a basement membrane, circular muscles, and longitudinal muscles. There is also a peritrophic membrane. There is, however, no cuticula in the mid-intestine. This division of the alimentary tract has a thick wall due to (1) the gradual transition of the epithelium from the flat cells of the oesophagus to the columnar type of the mid-intestine, and (2) to the infoldings of this epithelial tissue. Circular muscles are well developed throughout the length of the mid-gut, but longitudinal muscles are very few.

It is probable that the ring of epithelial cells surrounding the oesophageal valve does not secrete the peritrophic membrane, since it has an inner cuticular covering which is continuous with that of the oesophagus. Whether the epithelial lining of the mid-intestine secretes the peritrophic membrane has not been determined.

The type of secretion is probably holocrine, i. e., it is due to the destruction of cells of the inner epithelium (Plate IV, Fig. 7). On the inner surface of the epithelium there is no striated border, but there are numerous globules of secreted fluid "budding" off from the ends of the cells. In some cases it appears that the whole end of the cell is breaking away. Ends of some cells also seem to have transparent vacuoles.

New cells are formed in round outward extensions of the epithelium. Some of these extensions break through the basement membrane and constrict at the outer surface to form round cellular aggregations. Some of these epithelial masses lie in the muscles, detached from the inner epithelial layer. At intervals the inner epithelial layer itself extends through to the outer surface, forming papillae there. The separate masses may be regenerative cells, as also may be the papillae-like extensions. Their function could not be demonstrated.

The Hind-Intestine

The mid-gut tapers off somewhat abruptly to form the ileum. The six Malpighian tubules enter in this region. A longitudinal histological examination of this region of union between the mesenteron and hind-intestine shows that the pyloric valve is relatively simple—if it can be called a valve (Plate IV, Fig. 7). This examination also shows that the Malpighian tubules enter the alimentary tract just at the posterior extremity of the mesenteric epithelium, and anterior to the tongue-like projection of the cuticular covered epithelium of the ileum. Everly found in his study of the Margined Blister Beetle, that the Malpighian tubules entered just posterior to this intima-covered invagination of the epithelium. The intima of this epithelium is relatively thick. The wall of the ileum just posterior to the entry of the Malpighian tubules contains an abundance of circular muscles from three to five layers deep.

Posteriorly the ileum has a thin wall (Plate V, Fig. 12). The intima, as in the region of the oesophageal valve, does not have spines or tooth-like projections which were found in the Margined Blister Beetle by Everly. In *E. pennsylvanica* the intima of the ileum is relatively smooth. The epithelium consists of a single layer of short cuboidal cells. There is a single layer of circular muscle cells, but longitudinal muscle cells are few.

At the bend over the mesenteron where the hind-intestine turns laterally and posteriorly, the ileum and colon meet. In this bend there is an increase in the number of layers of circular muscles. Longitudinal muscles are present in this region definitely grouped around the circumference of the outer layer of circular muscles.

The colon extends from the above described bend of the hind-intestine to the rectum. The wall of the anterior colon is thick (Plate V, Fig. 10). It has large infoldings of intima which are filled with epithelium. Surrounding the epithelium are the circular muscles, four and five layers deep. These muscles are arranged in six symmetrical groups or bundles, and have the appearance of being "tied in" at six equidistant points by groups of several longitudinal muscles.

The colon enlarges gradually toward the rectum, the wall becoming thinner. At the posterior end the colon is about one and one-third times the diameter of the rectum, and about one-half the diameter of the mid-gut (Plate V, Fig. 13). The colon is constricted abruptly in the seventh abdominal segment to form the rectum.

The anterior rectum has from 10 to 12 cuticular invaginations filled with epithelium (Plate V, Fig. 11), which nearly fill the lumen of the rectum. The wall is quite thick, made up almost entirely of circular muscles, only a few scattered longitudinal muscles being present. The rectum enlarges slightly toward the anal opening. In general, the rectum is wrinkled in appearance, although this is somewhat obscured in gross dissection by the connective membrane which covers the colon and rectum.

The Malpighian Tubules

The Malpighian tubules, six in number, enter the gut at the anterior end of the hind-intestine. At the point of entry they are covered with

a broad ring of circular muscles (Plate IV, Fig. 8). There is also a definite covering of connective membrane evident in longitudinal and cross sections of the Malpighian tubules.

There are two semi-circular folds in the wall of the hind-intestine between the openings of each of the tubules (Plate IV, Fig. 9). There is no external indication of this; however, there is a clearing and smoothing of the region between the points of entry of the tubules, due to the absence of papillae. The opening of the Malpighian tubules into the lumen is surrounded by a ring of columnar epithelial cells (Plate IV, Fig. 8).

After many bendings throughout the body cavity the tubules enter under the connective tissue which covers the colon. They occur all along the colon under this membrane and end abruptly at the point where the colon constricts to the size of the rectum (Plate V, Fig. 13).

SUMMARY

In general, the morphology of *E. pennsylvanica* is like that of the Margined Blister Beetle as determined by R. T. Everly. There is little or no differentiation of the fore-intestine, except for a well-developed oesophageal valve. This valve has six finger-like pieces of chitin on its inner surface as it extends into the mesenteron. In this it differs from the Margined Blister Beetle which, according to Everly, has just four such chitinous "fingers."

Secretion is holocrine. There are evaginations of the mesenteric epithelium through the circular muscles to the surface of the mesenteron, forming papillae which are visible externally.

The Malpighian tubules, six in number, empty into the hind-intestine just at the point of union with the mid-gut, and not posterior to the poorly developed pyloric valve as was found in the Margined Blister Beetle by Everly. These tubules, after convolutions through the body cavity, enter under the connective membrane of the colon, where, with many short bendings, they extend to the rectal constriction of the colon. No connection with the lumen of the intestine in the region of the posterior colon could be demonstrated.

The ileum is somewhat muscular anteriorly, but the greater part is a thin wall of intima, epithelium, circular muscles, and a few longitudinal muscles.

The anterior colon has a well-developed muscular system. The circular muscles are "tied in" at six equidistant points by bundles of longitudinal muscles.

The rectum is quite muscular. The rectal lumen is well filled with invaginations of intima.

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ABBREVIATIONS USED ON PLATES

B M.....Basement Membrane.
C Mus.....Circular Muscles
CH.....Chitin.
COL.....Colon.
CT.....Connective Tissue.
EPI.....Epithelial Tissue.
FT.....Fat Tissue.
IL.....Ileum.
IN.....Intima.
L MUS.....Longitudinal Muscles.
LU.....Lumen.
M INT.....Mid-Intestine.
MALP.....Malpighian Tubules.
NI.....Nidus.
OES.....Oesophagus.
OV.....Oesophageal Valve.
PROV.....Proventriculus.
PV.....Pyloric Valve.
RECT.....Rectum.
SEC.....Secreting Cells.

EXPLANATION OF PLATES

Plate I

Fig. 1. A dorsal view of the alimentary tract in gross dissection.

Plate II

Figs. 2, 3, and 4. Three cross-sections of the oesophagus drawn to the same scale, showing the gradual enlargement of the oesophagus toward the mid-intestine.

Plate III

Fig. 5. Longitudinal section through the oesophageal valve, showing the sleeve-like extension of the oesophagus into the mesenteron.

Fig. 6. Cross-section of the extension of the oesophagus into the mesenteron showing the six chitinous fingers on the inner surface.

Plate IV

Fig. 7. Longitudinal section through the pyloric valve.

Fig. 8. Detail of cross-section of union of mid-intestine and hind-intestine showing the entry of Malpighian tubules.

Fig. 9. Diagrammatic drawing showing the distribution of the Malpighian tubules in a transverse plane at their point of entry into the hind-intestine.

Plate V

Fig. 10. Cross-section through the anterior colon.

Fig. 11. Cross-section through the rectum.

Fig. 12. Cross-section through the ileum.

Fig. 13. Longitudinal section through the colon and rectum, showing the constriction of the colon at the rectum, and the Malpighian tubules under the connective membrane of the colon.

FIG. 1

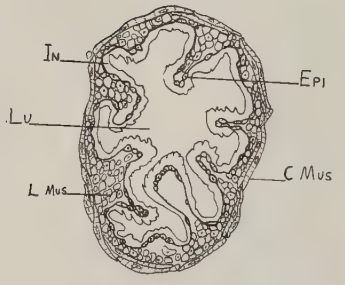
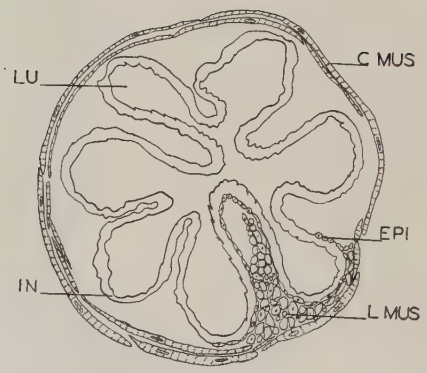


FIG. 2



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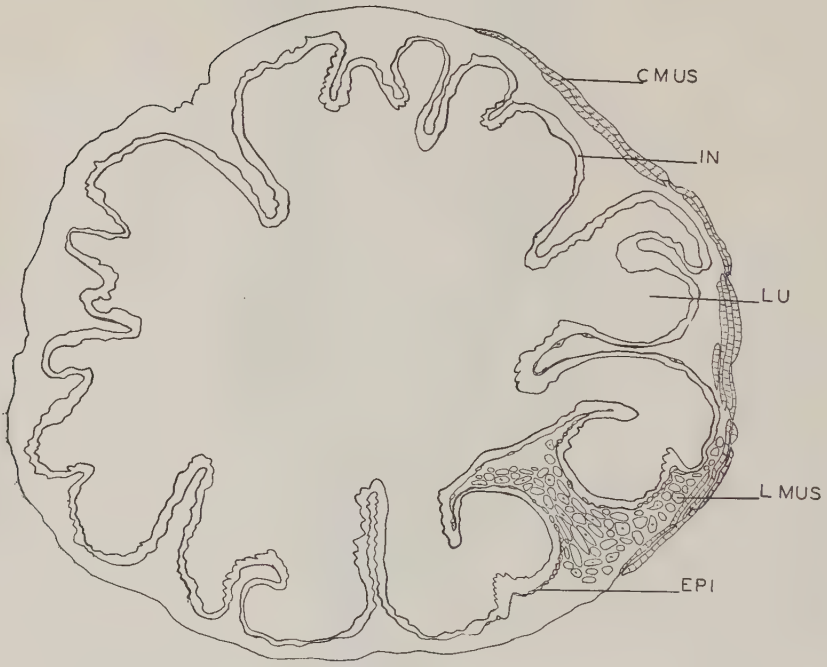

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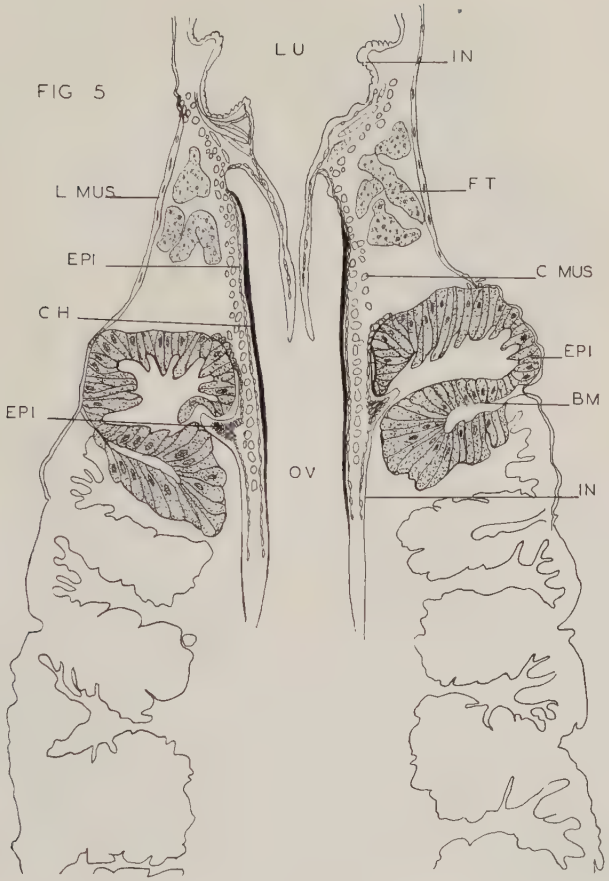

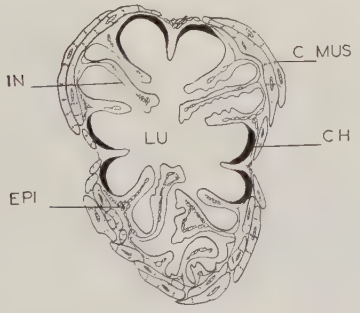

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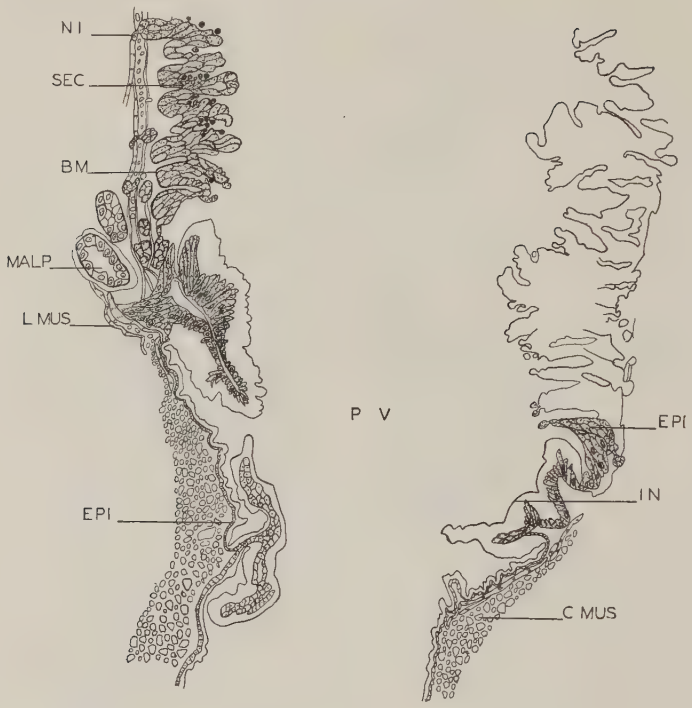

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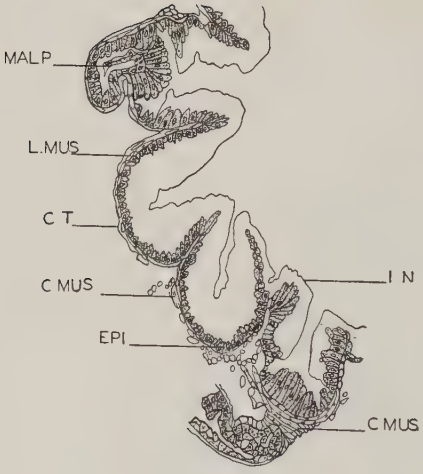

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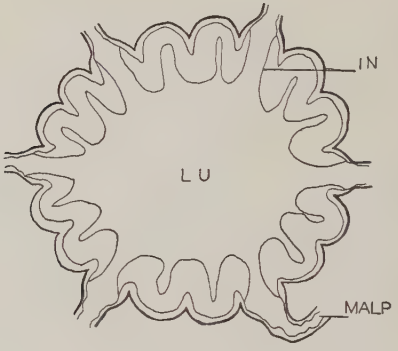

FIG. 9

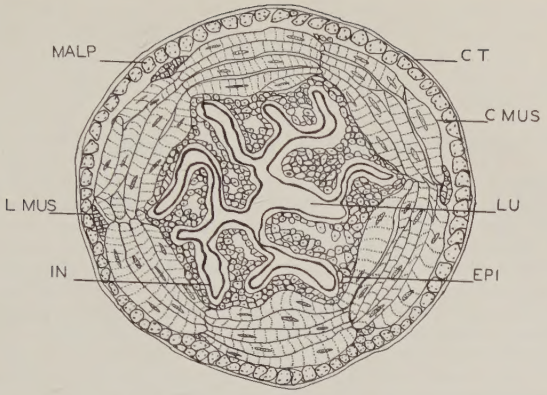

FIG 10

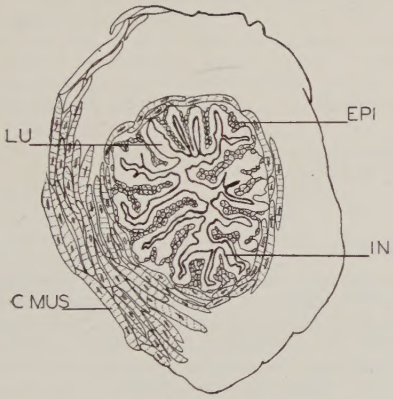

FIG. 11

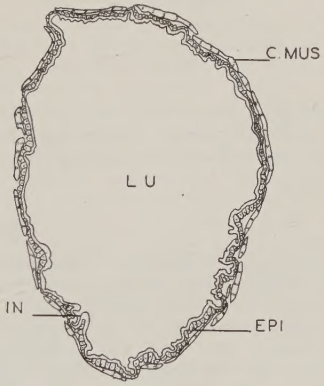

FIG. 12

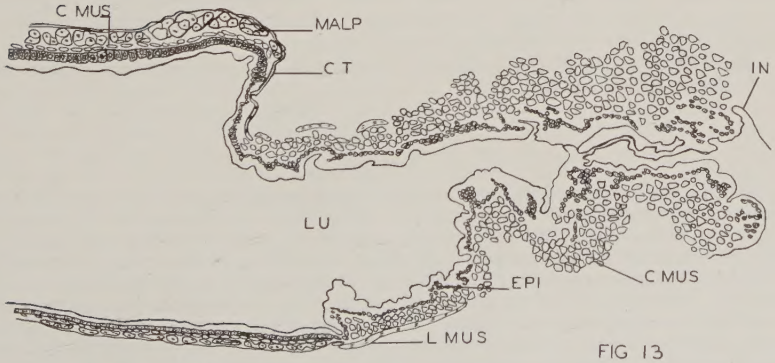

FIG 13

BOOK NOTICES

Fearfully and Wonderfully Made

Knowledge of the human organism grows apace, and it is fitting that from time to time attempts should be made to synthesize and correlate the available knowledge. The author of this volume, born and educated in Vienna, and with much chemical and medical research to her credit in the United States, has succeeded in bringing together in clear simple terms an astonishingly large number of facts about the anatomy, the physiology and the chemistry of man. Early in the book the author digresses to the philosophical consideration of asymmetric molecules and their bearing on living substance, and from time to time the phenomena of stereochemistry are reintroduced, until they become the dominant theme of the presentation. The author feels that stereochemistry reaches the very roots of biological principles, giving the unique specificity to the bio-molecule, and deplores the neglect of this science by biological workers. A most interesting philosophy of the living world is built around these considerations.

The hope is expressed that the interested layman will profit by the book, but it is the opinion of the reviewer that it would have to be an extremely inquiring and eager layman to wend his way through the tremendous mass of facts and emerge with much inkling of the author's philosophy. There is some tendency to redundancy in the volume, and a few grammatical errors, which detract from the pleasure of reading. However, the book should be stimulating to the philosophically minded biologist, bio-chemist and bio-physicist.—*L. H. S.*

Fearfully and Wonderfully Made, by Renee von Eulenburg-Wiener. xii+472 pp. New York, the Macmillan Co., 1938. $3.50.

Heredity Up-to-Date

Shull's "Heredity," for twelve years a standard and popular text in genetics, has been newly revised and issued in its third edition. The author has long been noted for his facile writing and clarity of presentation, and the new edition, extensively rewritten and reorganized, is a model of text-book preparation. Human material has been widely introduced throughout the book, without, however, replacing the chapters formerly given over to human heredity, which have themselves been considerably extended. The new knowledge of giant chromosomes has been made use of early in the book, the concept of genes and chromosomes being introduced in advance of examples of the inheritance of specific factors. Nearly 700 questions and problems of the objective type have been incorporated in the new edition, and a bibliography has been added. Practical applications of genetics, particularly to human beings, are thoroughly discussed. The book should appeal strongly to teachers and students alike.—*L. H. S.*

Heredity, by A. Franklin Shull. Third edition, xvii+442 pp. New York, the McGraw-Hill Book Co., 1938.

Cancer

Noting the success of the symposium type of program presented at the A.A.A.S. meetings, particularly as exemplified in the annual symposium of the American Society of Naturalists, the Medical Sciences Section determined to present at its 1936–37 meetings an extension of the plan. Accordingly there was prepared and offered a symposium on cancer, covering on a large scale a many-sided survey of this problem. Workers in various phases of cancer research presented papers at a series of sessions on seven successive days. As a result of the growing subsequent interest in the papers and the ensuing discussions, the symposium was printed in book form, and the present volume is the result. The thirty-one papers are clearly presented, well illustrated, and are by recognized authorities in the various fields. They are

grouped into the following general categories: heredity and constitutional factors; induction, stimulation and inhibition of tumorous growths; metabolism of cancerous tissue; radiation; general discussion of the cancer problem. While many of the papers are technical, others are more general and should be read by social workers and educators. Particularly Little's discussion of the social significance of cancer should have widespread publicity.—*L. H. S.*

Some Fundamental Aspects of the Cancer Problem. A Symposium. 248 pp. New York, the Science Press, 1937. $2.50.

Political Genetics Again

The controversy started by Graubard and by Muller against the more orthodox eugenists receives new fuel from this book by the distinguished geneticist of the University of London. While the book can not be said to be non-partisan, it is nevertheless a very fair presentation of the genetic implications involved in problems of racial inequalities, political discrimination and eugenical possibilities. The book is based on the Muirhead Lectures delivered at Birmingham University in 1937. In reading them one can only wish that it had been his privilege to hear them actually delivered, and perhaps to take part in the debate which must surely have followed their utterance.—*L. H. S.*

Heredity and Politics, by J. B. S. Haldane. 202 pp. New York, W. W. Norton and Co., 1938.

Scientific Orientation

Ten members of the faculty of the University of Rochester have conspired to produce this introduction to the sciences. In keeping with the trend of the times, it surveys the broad field of science, integrating the various specialties into a unified whole. The integration is well thought out. For example, geology is introduced twice, once in more general aspect preceding the study of chemistry, and again in its mineralogical aspects following the chemical discussions. Chemistry itself is presented in two parts, separated by a discussion of physics. Other subjects portrayed are astronomy, biology, paleontology, physiology, bacteriology, psychology and mathematics. As is almost inevitable when ten authors write individual chapters of a text, some subjects are better presented than others, but on the whole the book seems a remarkably successful attempt to introduce the beginning student to science, its implications and its applications.—*L. H. S.*

An Orientation in Science, by Watkeys and Associates. x+560 pp. New York, the McGraw-Hill Book Co., 1938. $3.50.

Making Biology an Exact Science

It has been said that the task of the biologist of today is to raise biology to the rank of an exact science. Most people using the phrase "exact science" probably have in mind a science which adapts itself to mathematical treatment. But mathematics, or at least conventional mathematics, is not to be regarded as the only method for systematizing scientific knowledge, as is convincingly shown in the recent study by Dr. J. H. Woodger entitled "The Axiomatic Method in Biology." This book is very unique, since it represents the first attempt to apply to biology the *axiomatic* or *logistic* method, using the symbolic logic of Whitehead and Russell's celebrated work, the *Principia Mathematica*. This type of mathematics, though non-numerical, is perfectly controllable, perfectly rigorous, and enables one to decide quickly and decisively whether or not any possible statement concerning certain biological variables and their possible relationships is true. The purpose of the book is therefore to furnish the foundations for a new concise language for systematizing biological theory. It is the opinion of the author that the axiomatic method may thus serve to eliminate from biological literature disputes which arise solely from the faults of its language. It may also serve in discovering new unsuspected truths or even entire new analytical methods. Particularly convincing of this viewpoint are the words of Whitehead: "It follows that there are an indefinite

number of purely abstract sciences, with their laws, their regularities, and their complexes of theorems—all as yet undeveloped. We can hardly avoid the conclusion that Nature in her processes illustrates many such sciences. We are blind to such illustrations because we are ignorant of the type of regularities to look for."

The first two chapters describe the construction of axiom systems, the choice of various classes of arbitrarily defined variables, the properties of certain relationships which these may bear to each other, and rules concerning the manipulation of the logical symbols in the deduction of theorems. Chapter III then develops an axiom system for biology and explores its applications in Genetics, Embryology, and Taxonomy. The author warns the reader that no startling revelations are to be expected among the theorems which are presented, since only the framework of a vast project has been undertaken. As a result of the logical inspection of Mendelism, however, some practical goals have already been attained, a system for grading the different types of inheritance, and formulae for computing the numbers of genotypes and genotypic matings under all conditions.

Anyone interested in theoretical biology will probably find much of interest in Professor Woodger's study, especially in the introductory chapters. To follow the outline of the biological calculus will, however, consume a great deal of time and study, and this will be necessary if the reader wishes to evaluate the book thoroughly and check for himself the author's claims for its usefulness.—*C. W. Cotterman.*

The Axiomatic Method in Biology, by J. H. Woodger, with Appendices by Alfred Tarski and W. F. Floyd. x+174 pp. Cambridge University Press, 1937.